A MODEL FOR DETERMINING COST AND TRAINING EFFECTIVENESS TRADEOFFS FOR TRAINING EQUIPMENT*

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ABSTRACT

This paper reports the status of Phase I of an ongoing project to develop a macro model describing the decisions involved in developing training equipment. The purpose of the model is to assist managers in making such decisions by providing information concerning the tradeoffs between cost and training effectiveness caused by different configurations and choices of equipment. After the development of a preliminary model, field research was conducted to determine the feasibility of testing such a model and to collect information to expand the preliminary version into a more pragmatic tool.

Results of the field work led to several conclusions. First, many of the types types of data needed to validate such a model are available, hence making such a project feasible. Second, an examination of the available data led to an expansion of the preliminary model to include training value of the various trainer characteristics. Third, much work is needed to develop longitudinal data bases of job performance before sound predictions can be made concerning the impact of trainer characteristics on technician performance after graduation.

PURPOSE

This paper reports the status of an ongoing project to develop a macro model to assist managers in making decisions concerning training equipment. The model is designed to permit comparisons of alternative equipment and configurations, and the associated cost and training effectiveness for the alternatives. The project was designed to meet the three objectives listed below:

(1) To develop a macro model for use in making cost/benefit tradeoffs between the various characteristics that may be utilized in training equipment, and to give both military and industry guidelines to justify decisions relating to trainer design.

(2) To determine the efficiency of a sample of trainers currently in use.

(3) To determine the relative cost and training effectiveness of various characteristics or capabilities that can be used in training equipment.

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BACKGROUND

The operational readiness of sophisticated military systems depends, to a great extent, on the skills of the technicians who maintain those systems. As the sophistication of current military equipment increases, the operational training for the use of such equipment becomes simpler. Conversely, the training of technicians to maintain the equipment becomes an even more complex task (1). In order to assist in the training of maintenance personnel, therefore, the Armed Services are increasingly relying on the use of maintenance trainers and simulators (2).

There are two basic reasons underlying this trend. First of all, it is assumed that training devices are capable of training a student at least as effectively as instruction which only utilizes actual equipment. In fact, research in instructional psychology suggests that the use of actual equipment for training purposes may be less efficient and effective than the use of training devices which permit greater latitude in material presentation (3). For example, a training device can be designed so that an overall task is broken into smaller, less complicated subtasks which can be more readily grasped by a student. In theory, this leads to a better eventual mastery of the whole task (4). Training devices also allow students to practice and observe procedures which, although necessary for competency, are potentially too dangerous in

terms of personnel and/or equipment safety for the neophyte to perform in the training environment (5). Finally, training devices are assumed to provide more efficient training due to their built-in capabilities which allow automatic student monitoring, decreased instructor demand for routine problems, and increased student experience and practice (6).

The second reason why training devices are becoming increasingly popular is that such devices are often assumed to be more cost effective than the use of actual equipment (7). The use of actual equipment in training situations is expensive in terms of such factors as fuel costs, equipment wear and tear or damage, and loss of availability for operation while diverted to training use. Therefore, even when the training effectiveness of a course utilizing a training device is only equivalent to that of a course utilizing the actual equipment, if the device is less expensive to acquire and run than the actual equipment, it is a better value for training purposes.

Although such reasons for using training devices are seductive in theory, these assumptions have not necessarily been found to be true in practice. Therefore, the question that arises is whether or not training devices are effective --either in terms of cost or training -- when compared with more traditional training methods. The principles of learning psychology have been found to fall short when practiced in military training situations (8). Many of the "common sense" characteristics often included in the design of training devices (e.g., high realism) have not been found to be consistently effective (9,10). Furthermore, although the primary goal of training is to produce qualified technicians more quickly, only one study has been performed to comparatively evaluate the effectiveness of technicians trained with actual equipment versus those trained using simulators. No differences were found between groups in this study (11). Virtually no research has been conducted relating life cycle costs to training effectiveness.

The lack of hard facts concerning the usefulness of various trainer characteristics makes training device justification and design tradeoffs difficult. Because of this, decisions are made based only on cost factors since there are no data available to evaluate training value. Therefore, both the Services' project managers and industry have been unable to articulate requirements for training devices in terms of projected training value. Equipment for training is often proposed, developed, and procured without an estimate of the expected training effectiveness and without a thorough analysis of which tasks are suited to the use of a training device or simulator. Such practices, however, mean that the creation of an optimally effective training device is only serendipitous.

Since effective training is vital for the development of the skilled technicians who are a key link in the chain of operational readiness (12), it is necessary that incompatibilities between current assumptions and actual data be identified and rectified. There is, therefore, a strong requirement that training efficiency and effectiveness be considered along with costs during the front end analysis and design of new maintenance training equipment. The formulation of consistent and effective policies for such designs depends to a great extent on the use of cost and training effectiveness data in a model of logistics, manpower, personnel, and training. The projections of such a model must be further clarified and validated using hard data collected from the field.

Two sets of factors must be dealt with in such a project: economic considerations and training quality. Historically, cost analysis has been accomplished for tradeoffs between actual equipment and simulators used for training. Cost considerations have been based on investment costs and efficiency items such as expected fuel savings. However, experience with successful training devices indicates that certain efficiencies which can also be assigned a dollar value accrue once the trainer is fielded. Examples of these are time saved in training, operational equipment made available for missions other than training, lowered investment costs, reduced maintenance costs, and less run time on operational equipment. Such potential efficiencies should be identified and developed into an economic model for use in prediction of life cycle costs during front end analysis.

The second set of factors which must be considered in such a project deals with differences in training effectiveness between courses using training devices and those using the actual equipment. Often the assumption is incorrectly made that if a training device is less expensive than the actual equipment as used in training, it is a better buy, and, therefore, should be used. This line of reasoning is specious. In order to justify the use of a training device, it is fallacious to consider only the costs of acquiring and maintaining it. Attention must also be focused on how well each facilitates student learning, and on the resulting benefit of more quickly producing qualified technicians. While effectiveness is not easily quantifiable, there are enough indicators to believe that, at least in gross terms, it can be measured and modeled. Such information would be helpful in making sound management decisions on the value of simulators for training.

The evaluation of the cost and training effectiveness of maintenance simulators and trainers is not a new idea. In past studies, investigators have typically examined variables such as acquisition costs and training effectiveness in the school setting (13). Military training, however, is intended to prepare personnel to perform various jobs in operational units. Therefore, the true measure of effectiveness is actual job performance rather than performance with in a training course. Similarly, although comparisons between acquisition costs of training devices versus other training methods are an important consideration, it is also necessary to consider the comparative life cycle costs of these methods before an informed decision can be made. Such an examination must be accom-

plished over a broad spectrum of applications before an ultimate criterion of training program effectiveness can be established or predicted.

Two types of tools are necessary in order to make sound, knowledgeable decisions during the development of maintenance trainers. The first of these tools is a macro model which can be used as a high level filter in making design decisions and determining device justifiability. This type of model would act as a decision screen, specific only enough for early decision making by program managers. Concomitant with such a decision screen, a more specific, pragmatic design screen must also be developed. This type of tool could be used effectively both on a lower level in DoD and in industry for making specific cost/training effectiveness tradeoffs in the design of future training devices.

PHASE I: FIELD STUDY

Phase I of this project was designed as a pilot study to identify potential efficiency and effectiveness factors, and to develop a prototype model with them. Maintenance trainers were chosen for analysis in this phase of the study for the following reasons:

(1) Cost indicators and potential savings are not obvious as in the case of flight simulators where flying hours have a known cost. Thus, the study avoids the issues of expressing cost avoidance as an efficiency, and permits a focus on more subtle cost savings as well as highlighting concern on effectiveness issues.

(2) Instances exist in maintenance training where individuals in the same skill and weapon system were trained in different ways -- some with actual equipment and others with training devices. This situation allows the collection of control data better suited for making judgments of the relative cost and training effectiveness of courses using training devices versus those which do not.

(3) The factors leading to the design of an effective maintenance trainer are much less well defined than for operator trainers. Therefore, if the characteristics leading to effective design can be determined and put into a model for maintenance trainers, it is probable that attempts to generalize such a model would be much less difficult than if the model were first developed for operator trainers.

(4) Emphasis on ways to enhance maintenance training to offset design, support, and manpower problems has forced DoD to look at ways to improve and expedite support training. Selection of maintenance trainers for this work is consistent with the DoD emphasis to improve training for maintenance.

Preliminary Model

As discussed earlier in this paper, in order to develop a valid tool to make knowledgeable decisions concerning device cost and training effectiveness tradeoffs, four levels of variables must be considered:

(1) Training effectiveness in the school;
(2) Training effectiveness in the field;
(3) Acquisition costs of equipment;
(4) Life cycle costs of equipment.

However, although necessary in the creation of such a tool, these factors are not sufficient in and of themselves. There are also several modifying variables which, although not directly relating to device effectiveness, act as filters integral to any comparison between the effectiveness of a training device versus the actual equipment (Figure 1). First of all, the goals of various maintenance training programs differ, and the principles of instructional technology do not lend support to the supposition that the same type of training will be equally efficient for all purposes. (For example, if the goal is to teach the student motor skills sucn as performing a task requiring interactive analog inputs, one would probably not depend wholly on a verbal explanation -- without hands-on practice -- to teach such a task.) Therefore, in order to compare the relative effectiveness of training programs, it is important to keep in mind the objectives toward which the learning situations are aimed. A second filter which must be considered in the creation of such a model is the characteristics of the students being taught. For example, in teaching a low level student with vitually no experience or knowledge in the subject area it would be necessary to go into much more detailed explanations of the subject matter than when giving a review course to students who had been performing the same task for over a year. A third filter which one must be aware of in facing such comparisons is the characteristics of the instructor teaching the course. For example, if an instructor does not understand or like to use a particular technique for teaching, he or she will not utilize the method as well as an instructor who does.

Therefore, although comparing the relative effectiveness of maintenance trainer equipment and actual equipment training is theoretically a straightforward task, it is important to consider these modifying variables --program goals, student experience and aptitude, and the instructor experience and aptitude -- in order to meaningfully interpret any results of such a comparison (Figure 1).

This framework was used as a preliminary paradigm to describe the field of training device cost and training effectiveness factors. The Phase I field study was then designed to test the effect of the independent variable of training method on the four levels of device effectiveness, taking into account the modifying variables discussed above. The objectives

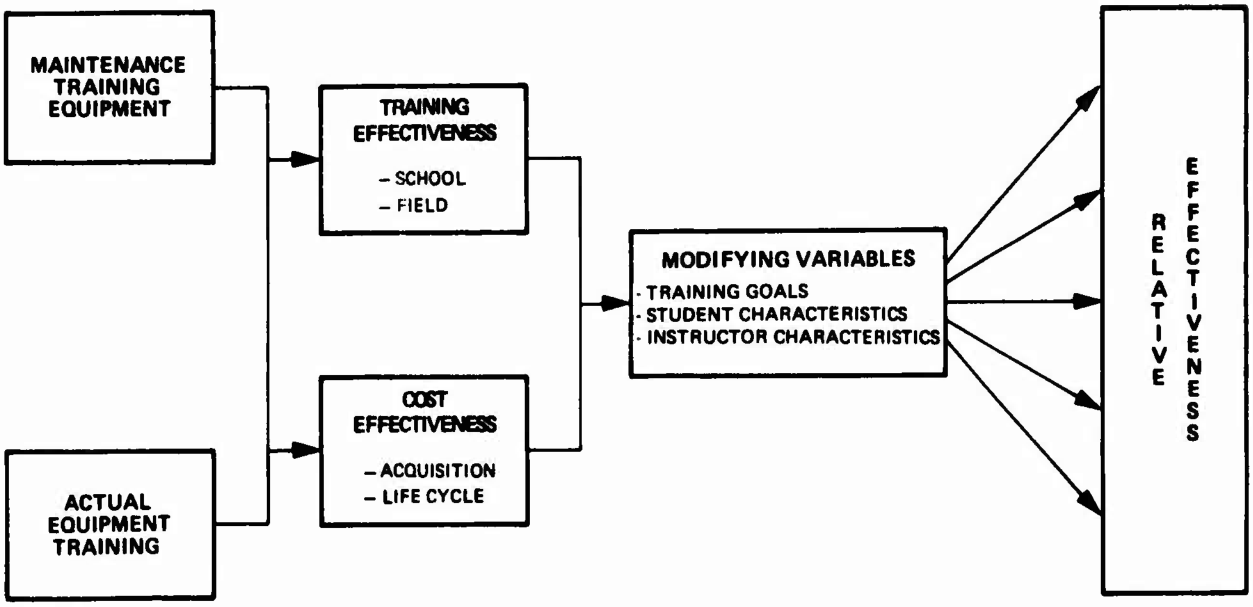

Figure 1. Paradigm for Determining Relative Effectiveness of Two Training Methods

of this field study were to collect information to develop this initial paradigm into a testable model, and to determine the feasibility of collecting data to test the model.

Methodology

To help achieve these objectives, two sets of data collection instruments were developed. The first of these was a set of Behaviorally Anchored Rating Scales (BARS) which were used to assess technicians' performance in the field. In order to develop these scales, instructors in the role of subject matter experts were asked to create a series of critical incidents describing behaviors which differentiate between a good technician and a poor one. These incidents focused on specific technician actions closely related to the job, and differentiated between success and failure as a maintenance technician. Several hundred of these incidents were collected, thematically analyzed, and placed into scales. They were then rated by the instructors on a seven-point scale with the scale value of 1 being very poor performance behavior and the scale value of 7 being very high performance behavior. Those incidents with the lowest standard deviations and means closest to 1 and to 7 were then placed on a graphic type rating scale to be used as behavioral anchors for the scale.

There are two advantages to using BARS. First, the description of the scale points is written in terms that can be easily understood by the raters. Second, since the type of person who developed the scale is also the type of person who uses the scale, the raters have a vested interest in using the scales correctly (15).

The use of the BARS development technique in this study yielded seven specific scales:

1. Safety: Behaviors which show that the technician understands and follows safety practices as specified in the technical data;

2. Thoroughness and Attention to Details: Behaviors which show that the technician is well prepared when he arrives on the job, carries out maintenance procedures completely and thoroughly, and recognizes and attends to symptoms of equipment damage or stress;

3. Use of Technical Data: Behaviors which show that the technician properly uses technical data in performance of maintenance functions;

4. System Understanding: Behaviors which show that the technician thoroughly understands system operation allowing him to recognize, diagnose, and correct problems not specifically covered in the Technical Orders and publications;

5. Understanding of Other Systems: Behaviors which show that the technician understands the systems that are interconnected with his specific system and can operate them in accordance with technical orders;

6. Mechanical Skills: Behaviors which show that the technician possesses specific mechanical skills acquired for even the most difficult maintenance problems; and

7. Attitude: Behaviors which show that the technician is concerned about properly completing each task efficiently and on time.

These seven skills were found to be generic, holding true for both systems utlimately chosen for this study phase.

The second data collection instrument was a series of questionnaires for students, instructors, and technicians. These questionnaires were designed to collect two types of information: (1) demographic information on subject background, training, and experience; and (2) subjective information such as subjects' attitudes toward training devices in general, and their perceptions and evaluations of the specific device with which they were working.

For this phase of the study, the F-16 and E-3A AWACS Navigation Maintenance trainers were selected to serve as the data sources for the development of the preliminary model. These trainers are two of the most recent examples of maintenance trainers in the field. The F-16 trainer consists of a series of six freeplay systems designed to assist in teaching maintenance courses in the flight controls, Comm/Nav, electrical systems, engine start, engine diagnostics, and engine run for the F-16 aircraft. The AWACS device is a procedural trainer designed to be used in courses in navigational system maintenance.

Data for this phase of the study were collected from subjects who had used these two training devices, and also from control subjects who had gone through the same courses without using the training devices. The training effectiveness soft data were collected using the three versions of the questionnaire to gather background data concerning the subjects and their opinions of training courses and devices. The BARS were used to determine the instructors' performance appraisals of those students having just completed the course and of those having previously taken the courses. Supervisors' performance appraisals were obtained for technicians having recently graduated the courses, and for those who had previously graduated the courses. This redundant use of the BARS was done in order to help determine the validity of such subjective judgments, and to partially ascertain the relationship between judgments of technician performance at the school and field levels.

Hard data of training effectiveness were collected through student course test scores and Work Unit Code (WUC) information. WUCs yield hard data concerning group and individual level technician performance in the field in such areas as removal time, repair time, retest OK (RETOK) rates, etc.

Data concerning the acquisition and life cycle costs for courses utilizing and not utilizing the trainer were also collected through the Air Force and the contractor. These field study data are summarized in Tables 1 and 2. Missing data in the tables result from the normal vicissitudes of subject availability encountered in a field study of this nature.

Table 1. Data Collected in Phase I Field Study

TRAINING EFFECTIVENESS STUDY			
School		Field	
F-16	AWACS	F-16	AWACS
Soft Data	Soft Data	Soft Data	Soft Data
• Instructor Interviews	• Instructor Interviews	• Technician Interviews	• Technician Interviews
• Student Interviews	•		
• Instructor Questionnaires	• Instructor Questionnaires	• Technician Questionnaires	• Technician Questionnaires
• Student Questionnaires	•		
• Instructor's Performance Appraisal of Student (BARS)	• Instructor's Performance Appraisal of Student (BARS)	• Supervisor's Performance Appraisal of Technician (BARS)	• Supervisor's Performance Appraisal of Technician (BARS)
Hard Data	Hard Data	Hard Data	Hard Data
• Test Scores	• Test Scores	• Work Unit Code (WUC's) Information	• Work Unit Code (WUC's) Information

Table 2. Data Collected in Phase I Field Study

COST DATA			
Acquisition		Life Cycle	
F-16	AWACS	F-16	AWACS
Hard Data	Hard Data	Hard Data	Hard Data
• Developmental Costs	• Developmental Costs	• Consummable Materials	• Consummable Materials
• Equipment Costs	• Equipment Costs	• Rate of Revision	• Rate of Revision
• Instructor Training Costs	• Instructor Training Costs	• Equipment Maintenance Costs	• Equipment Maintenance Costs
• Instructor Preparation Time	• Instructor Preparation Time	• Equipment Availability	• Equipment Availability
• Area Requirements	• Area Requirements	• Life Span of Equipment	• Life Span of Equipment
		• Fuel/Support Equipment Costs	• Fuel/Support Equipment Costs
		• Instructor Preparation Time	• Instructor Preparation Time

Revised Model

Although it was recognized during the construction of the preliminary model that trainer characteristics are an important variable directly impacting the effectiveness of training devices, a comprehensive list of these characteristics could not be developed until the views of the users were collected and the impact of the various charateristics on effectiveness were observed. This information showed that by and large the greatest "need" perceived by users was for high "realism". As stated earlier in this paper, training literature does not totally support such a statement of need. However, after close examination of the data, it was found that the discrepancies between the findings in the literature and the "universal" statements by the users were to a great extent a result of the lack of a consistent definition for the term "realism". For example, when one instructor stated the need for high "realism" in the design of an engine trim box to teach a motor skill, he was not necessarily referring to the same device characteristic as an instructor asking for high "realism" of engine sounds. As a result, the characteristic of "realism" was replaced for the purposes of this model by the taxonomy listed below.

1. Static Realism

   a. Visual Realism: The extent to which the device components or subsystems appear to be the same as on the actual equipment.

   b. Spatial Realism: The extent to which the device components or subsystems are physically situated as on the actual equipment.

   c. Auditory Realism: The extent to which the device components or subsystems approximate the sounds of the actual equipment.

   d. Kinesthetic Realism: The extent to which the device components or subsystems approximate the feel of the actual equipment.

2. Dynamic Realism

   a. Temporal Realism: The extent to which the reaction time and response of the device components, or subsystems approximate the actual equipment.

   b. Extent of Simulation: The extent to which the device as a system approximates the total responses of the actual equipment rather than only following the responses given in the technical data.

The other training device characteristic which many users felt was important to consider was computer aided instruction (CAI). This too appeared to be a taxonomy rather than a single variable:

1. Student Aids: Those computer managed functions which directly aid the student to learn the material.

2. Instructor Aids: Those computer managed functions which indirectly aid the instructor in teaching the student the material.

3. User Aids: Those computer managed functions which facilitate the student's use of the training device.

Based on these taxonomies and the information collected in the field, the preliminary model was revised to expand the description of the parameters to be considered in the design and development of a training device. (This revised model is graphically depicted in Figure 2.) The subjective data collected supported the hypothesis of the influence of modifying variables on training effectiveness. Of the three original modifying variables considered, support was found to justify further investigation of the effects of both student characteristics and training program goals on training effectiveness. Information about these two characteristics consistently suggested that "lower level" students --where this is defined by skill, knowledge, or experience -can best be taught using different techniques than those used for "higher level" students. Similarly, the data suggested that different sets of device characteristics would best be utilized in teaching different program goals (e.g., mechanical skills or theoretical troubleshooting).

The attitudes of an instructor toward a training device, however, (although logically related to how well the device is used by the instructor and how well the student uses and learns from the device) were not found to significally impact training effectiveness in the sites and programs investigated in Phase I. In the two programs studied, the instructors as a whole were rather ambivalant towards the devices when they first began to use them, but they became more positive as their experience with the devices increased. Although this may cause differential effects in training between students taught directly after trainer acquisition as opposed to those taught later, the effects of this variable appear to be equated over a period time. A lesson to be learned here, however, is that improved instructor training immediately following the fielding of the training device can positively impact the acceptance and use of the device.

Although the modifying variables mentioned above have significant impact on the quality of training and must be considered in the interpretation of effectiveness data, the characteristics of the device itself are of superordinate importance in their effect on cost and training effectiveness. For the purpose of this model, "effectiveness" is defined as a relative term. Since training effectiveness cannot currently be judged on an absolute scale, it must be examined through a comparison between the quality of technicians in the field who have been taught using a training device versus those who have not. The relationship of these characteristics to the overall model is represented to the horizontal "slice" depicted in Figure 2. In Figure 3, one of these "slices" has been rotated 90 degrees in order to give a clearer view of its components.

At this level, the model can potentially aid in making more pragmatic decisions concerning the design of training devices. Given a sound definition of training device cost (as defined both by acquisition and life cycle costs), and the establishment of a sufficient data base, it will be relatively easy to determine the cost associated with different training device designs under consideration. For example, in low quantities, those characteristics defining static realism are relatively low in cost as opposed to those characteristics defining dynamic realism. The missing factor in the design and development considerations of today, however, is the concomitant consideration of comparative training effectiveness. By developing a large enough data base, it will eventually be possible to generate a series of equations which will allow managers to make decisions as to the relative training effectiveness of various alternative design configurations under consideration. It will then be possible to determine not only the cost of acquiring and using a training device, but also the training effectiveness of such a device relative to the actual equipment. For example, in Figure 3, for a certain training goal and student level there are hypothetically two different configurations which could be used in the design and development of a trainer, both of which would be equivalent to each other and to the actual equipment in terms of training value. The recommendation would then be to either use the more cost effective of the two alternatives, or to increase the projected level of training effectiveness by selecting a device configuration higher on the Y-axis.

The development of this paradigm into a useable tool for managers depends upon the creation of performance measures to determine the training value of various design characteristics. Once this is accomplished, tradeoffs between cost and training effectiveness can be determined. It should be recognized that the design characteristics for a training device or simulator are the driving factors in effectiveness potential and are also the major determinants of the utlimate cost. This leads to the conclusion that cost and benefit tradeoffs can be made for design characteristics once the manager determines specific training objectives. It will then be possible to approach the larger question of comparing cost and training effectiveness in order to make a rational choice between equipment alternatives.

PHASES II AND III: MODEL REFINEMENT AND VALIDATION

The model as described above was developed using two maintenance trainers. Before it can be considered as a viable instrument which can be applied to other maintenance training devices it must undergo validation and refinement. To do this, it must be ascertained whether the parameters of the model validly apply to other maintenance training device systems, whether the indicators of cost and training effectiveness are meaningful for the evaluation of maintenance training devices, and whether the design characteristics included in the model significantly impact the usefulness of the device in terms of these indicators.

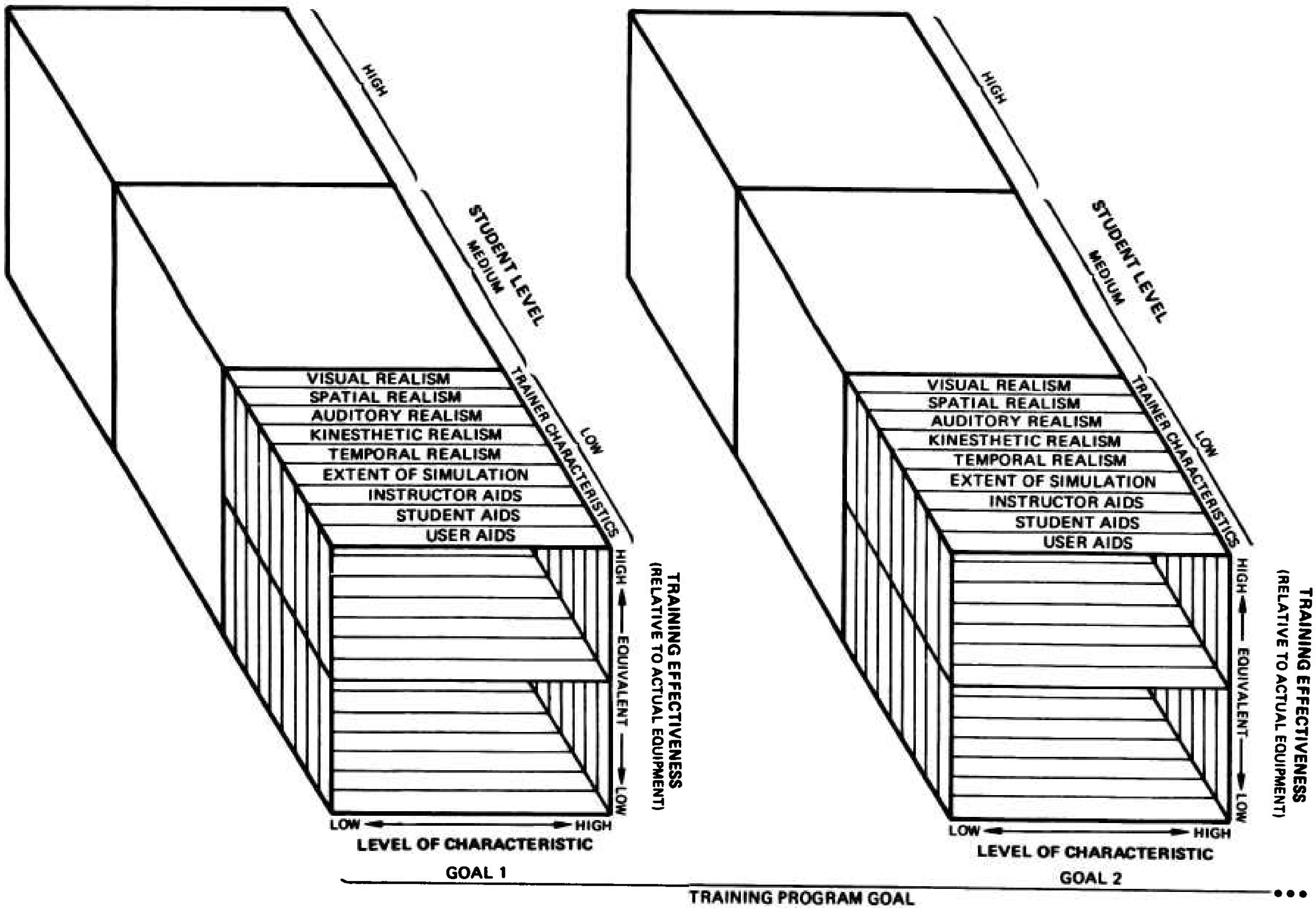

Figure 2. Revised Model for Determining Relative Effectiveness of Two Training Methods

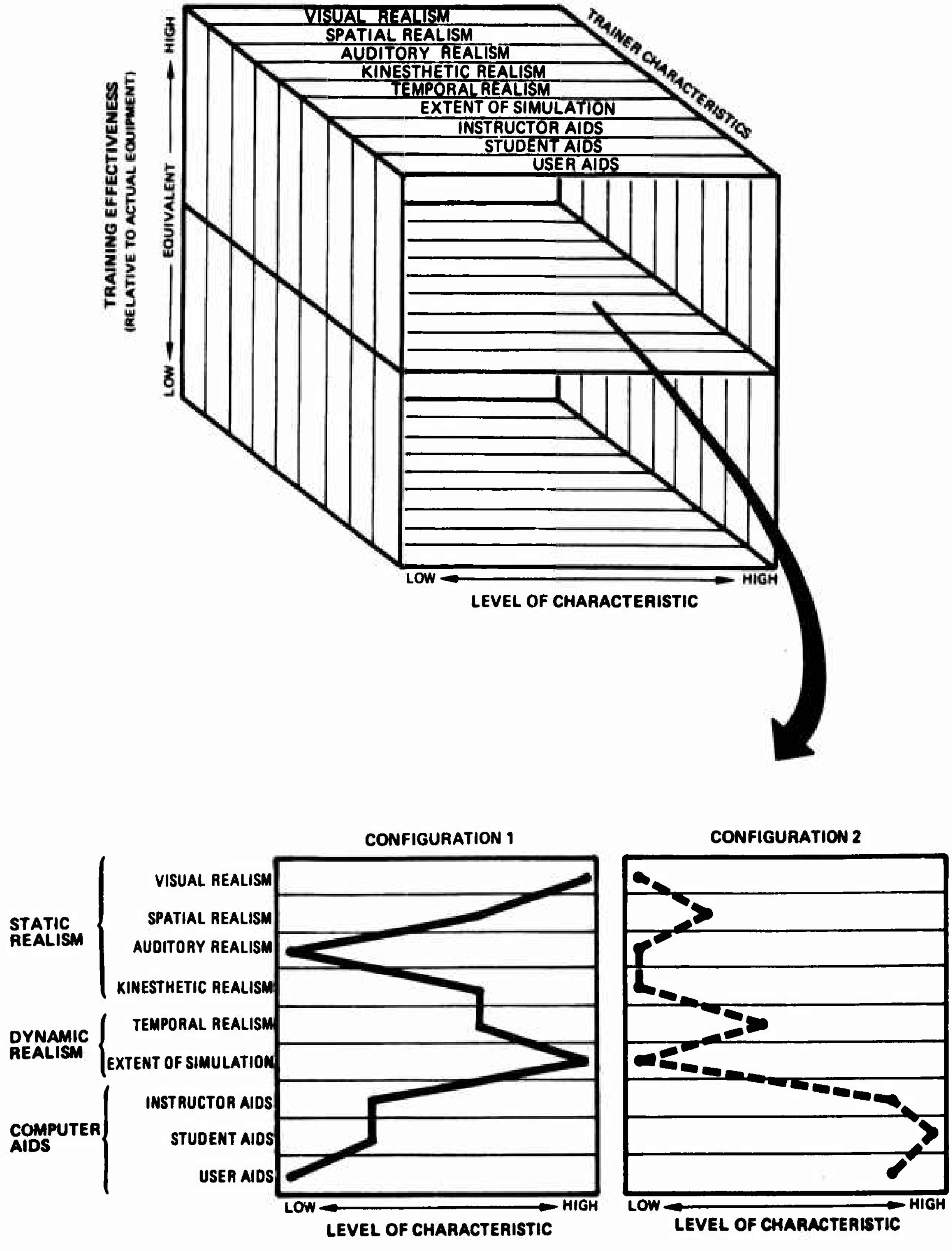

Figure 3. Detailed View of Revised Model

Although this model has intuitive appeal, it cannot be used until it is validated. In the future, it will be necessary to collect longitudinal data along various points of the characteristics continua and relate these to both cost and training effectiveness. Such a validation must be longitudinal, to say the least, and is outside the scope of the present study. Validation at this point in time will consist of collecting comprehensive data on the training systems currently in the field. The systems will be rated rated and placed on the characteristics continua, and used as inputs for the model validation and refinement.

The next step will be to collect data from courses using maintenance training devices and their concomitant control courses. These data will be analyzed in terms of the structure of the model to test for goodness of fit. The model will then be refined in order to better account for all data based on any mismatches in the comparison. Once the model has been refined in Phase II, it will be further validated using a broader spectrum of training devices and simulators. Much is already known about requirements for development and design of an effective operator trainer. Phases I and II of the current study will offer significant parallel data for maintenance trainers. This information will be synthesized and validated for the creation of a generic model in Phase III.

Several types of questions are to be answered in Phase III. If the indicators of cost and training effectiveness are found to be valid for maintenance trainers, are they equally valid for operator and crew trainers? Do these indicators apply equally well to part task training devices and to system devices? These kinds of questions must be answered over time before the model can be thought of as a univeral tool to be used by management.

During the Phase III validation, each service will be asked to apply the model throughout development and acquisition of an emerging system. Use of the model during this phase will be controlled only to the extent that each element of the model must be investigated. (Conditions may exist where one or more of the elements may not apply to the chosen system. It is important, however, that as much information as possible be collected concerning all parameters.)

The prediction of performance data will clearly be the most difficult to validate. This is compounded by the fact that not enough attention has previously been given to the systematic gathering of such information. As a result, there is a lack of a sufficient data base. Job performance data for the two systems investigated in this study were limited to a comparison of WUC items, time to repair, RETOK rates, etc. Other performance measures were subjective. Since the purpose of collecting these data was to establish their usefulness as indicators of effectiveness rather than to evaluate trainers, their use for this phase was acceptable. In the validation phase, however, it is reasonable to estimate probable effectiveness gains on emerging systems from using performance data from existing systems. These estimates could then serve as a basis for selecting design features and justifying design decisions.

DISCUSSION

The model presented above was prepared as an archetype, showing examples of the types of considerations which need to be made in the creation of training devices. Such considerations will aid in making knowledgeable decisions relative to cost and training effectiveness during device development and design. Although the model is empirically based and analytically developed, it is not without shortcomings which primarily reflect the state of maintenance training the Armed Services today.

The concensus of field personnel is that training courses such as those being studied in this project are of insignificant value to training except for use as a general overview. Rather, many people feel that the most valuable training is done during on-the-job training (OJT). This assumption is partially supported by the previous literature in which no differences are found between the performance of students having been through courses using actual equipment and those who went through courses using a training device. As stated in the introduction to this paper, one of the shortcomings of this research is that the focus has been primarily on effectiveness vis a vis the school situation rather than the actual field situation. However, the very structure of maintenance training in the Services supports this assumption: students are taught basic information in the school and more specific information through either formal or informal OJT upon graduation. Therefore, all technicians will eventually reach a minimum standard of qualification for the job: if not, they will be moved into a different job classification. As a result, the question is not how effective is the training, but rather how quickly does the student reach the level of minumum qualification (Figure 4).

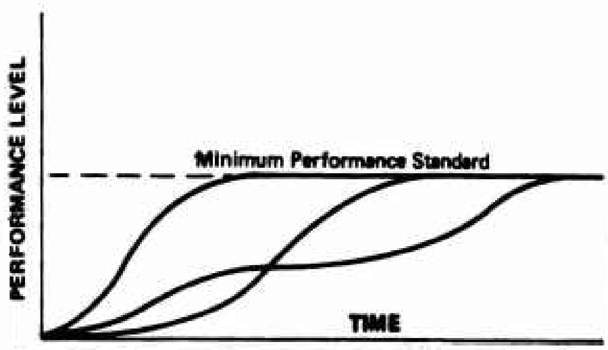

Figure 4. Comparative Rates with Which Various Training Courses Prepare Students to Meet Minimum Standard of Performance

Such criterion-referenced measures of training effectiveness may no longer be appropriate since the advent of training devices. It is not safe to assume that because a training course has been taught in a classroom using actual equipment as an adjunct, that a training device must be designed to fit this mode. This, coupled with the fact that there have been vast

advances in instructional technology, suggest that now is a good time to reevaluate current training methods, and devise a system which will enhance effectiveness in an absolute, not just a relative, sense. It is not necessarily logical to take the same course documentation, as is currently done, and exchange the terms "training device" for "actual equipment."

There is another difficulty which hinders the development of devices which are more training effective than the actual equipment. Although there have unquestionably been advances in the area of instructional technology over the past ten years, in the main there is no empirical evidence to support their effectiveness. Researchers have been pleading for more background investigation into these areas. However, although virtually every technical paper on the topic seems to end with a statement of this need, the research itself is being done slowly. If we truly wish to improve the quality of maintenance technicians -- and concomitantly the operational readiness of the Armed Services -- it is well past the time to earnestly investigate these matters. More comprehensive performance data must be collected, and a longitudinal data base developed so that meaningful judgments of effectiveness can be made.

Some of the reasons for the lack of empirical evidence supporting the worth of training devices vis a vis effectiveness have been discussed in this paper. However, the lack of such evidence is not surprising: course approach does not change with the addition of a trainer; better instructional technology is not implemented in trainer design; the usefulness of the various instructional technologies is not known and is not being researched. Training devices currently represent an engineering solution to a nonengineering problem. This must be changed. Creative designs and solutions in training terms must be applied in the development of such devices, with the application of new techniques to this new technology.

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